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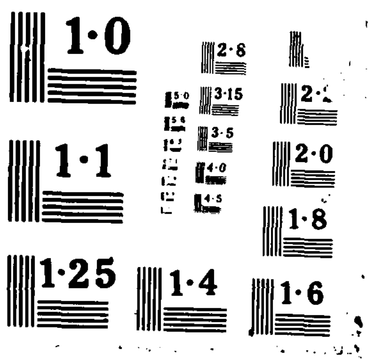
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IMAGING MULTISPECTRAL BURN DEPTH INDICATOR

ANNUAL AND FINAL REPORT

Martin A. Afromowitz

September 30, 1987

Supported by

U. S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Frederick, Maryland 21701-5012

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This research program successfully developed a real-time video imaging system (the Imaging Burn Depth Indicator) which can discriminate between areas of burn wounds expected to heal in three weeks or less from the day of injury, and those areas not expected to heal in that time period. The analysis can be performed on or about the third day post-burn on debrided burn wounds. Early evaluation of burn healing probability is a crucial factor in the decision to tangentially excise the burn wound.

In our clinical tests, the instrument was more accurate in predicting burn healing than the participating burn surgeons. Yet, the system can be operated by a person of average intelligence with no specialized burn training. Thus, with this instrument, evaluation of burn victims and selection of treatment modalities may be accomplished in the absence of qualified burn specialists.

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SUMMARY

This research program successfully developed a real-time video imaging system (the Imaging Burn Depth Indicator, or IBDI) which can discriminate between areas of burn wounds expected to heal in three weeks or less from the day of injury, and those areas not expected to heal in that time period. The analysis can be performed on or about the third day post-burn on debrided burn wounds. Early evaluation of burn healing probability is a crucial factor in the decision to tangentially excise the burn wound.

The IBDI measures the reflectivity of the burn wound in the red, green, and near infrared wavelength bands, which data correlates with burn healing probability. The instrument uses an algorithm established in an earlier study to translate this optical data into burn healing probabilities.

The IBDI produces two types of images: a true-color image of the burn and a false-color image of the burn. The false-color image consists of up to four colors, each of which indicates a distinct range of probability that the area of the burn so colored will heal within 21 days.

During the first year of this contract, the instrument was designed and fabricated. During the second year, the system was tested in a clinical setting at the Burn Center at Harborview Medical Center, Seattle, Washington.

Over one hundred burn wound sites were studied. Burn sites were evaluated on day three post-burn by our instrument and by the attending physician. Of those sites predicted by the instrument to heal in fewer than 21 days, the IBDI was correct 91% of the time. Of those sites predicted to not heal within 21 days, the IBDI was correct 85% of the time. By comparison, the predictions of burn surgeons supervising the care of these patients were as follows: 76% correct on burns predicted to heal within 21 days, and 67% correct on burns predicted to not heal within 21 days.

In our clinical tests, therefore, the instrument was more accurate in predicting burn healing than the participating burn surgeons. Yet, the IBDI can be operated by a person of average intelligence with no specialized burn training. Thus, with the IBDI, evaluation of burn victims and selection of treatment modalities may be accomplished in the absence of qualified burn specialists.

FOREWORD

For the protection of human subjects the investigator(s) have adhered to policies of applicable Federal Law 45CFR46.

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STATEMENT OF THE PROBLEM

Even in the best of circumstances, assessment of the healing potential of a fresh burn is very difficult. Although very shallow burns and very deep full thickness burns can generally be identified, burns that fall in the partial thickness to full thickness category cannot generally be characterized accurately during the first week or two post-burn. Modern burn wound management practice, which strives towards early excision of full thickness burns, would be markedly improved if burn surgeons had an accurate diagnostic method which could identify full thickness burns early on, preferably as soon as the burn wound stabilizes on or about the third day post-burn.

The need for early and accurate assessment of burn injuries in the military environment is even more urgent than that encountered in civilian situations. However, two problems arise. In the first place, the standard "eyeball" techniques used by even the most experienced burn specialists to assess burn depth are not very accurate, especially on burn wounds that are deep dermal or full thickness. Secondly, the relative inexperience of field medical personnel in diagnosing burn injuries may be expected to further contribute to poor burn management decisions on the battlefield.

Our previous research showed that the optical reflectivity of burn wounds in the red, green, and near infrared bands correlated very well with burn healing time as early as the third day post-burn. The present research contract was directed at developing an automated, nearly real-time, clinically useful imaging system that could provide the burn staff with a false-color picture of the burn wound, wherein each area of the wound is accurately characterized as to its healing probability.

BACKGROUND

As early excision plays an ever increasing role in burn management, knowledge of the time required for healing becomes crucial. If small to moderate sized burns that will not heal within three weeks are excised and grafted within the first five days post-burn, the patient could be discharged as soon as the donor sites heal. The entire hospitalization would rarely extend as long as three weeks. On the other hand, if the burn can heal on its own in less than three weeks, the patient can be spared operation, donor sites, and blood transfusions. In general, such superficial burns heal without scarring, and the hospitalization is no more than three weeks. Mistakes are made on both sides. A wound estimated to be superficial enough to heal in three weeks, that eventually requires grafting or does not heal for four or more weeks, markedly prolongs the patient's hospital stay. On the other hand, wounds that are quite superficial are sometimes incorrectly classified and needlessly excised with the attendant risks of surgery. For all these reasons, an early estimate of healing time becomes a crucial factor in modern burn management.

The instrument we have developed is intended to fill the gap in burn diagnosis described above. The Imaging Burn Depth Indicator (IBDI) is based on several years of experimental and theoretical research conducted at the University of Washington on the optical properties of burn wounds [1-6]. Key results of this earlier research are summarized below:

- Theoretical analysis of the optical properties of clean (debrided) burn wounds showed that the reflectivity of red, green, and near infrared light is a function of the eschar thickness, the volume fraction of blood in the tissue near the surface of the wound, and the oxygen saturation of the perfusing blood. These parameters correlate very strongly with burn depth and burn healing time.

- Measurements of the optical reflectivity of burn wounds on the third day post-burn in the red, green, and near infrared bands were strongly correlated with time-to-healing. In one major clinical study of 569 burn sites, our optical burn wound characterization analysis discriminated with 77% accuracy between burn sites that would or would not heal within 21 days of injury. Obvious superficial and obvious full thickness burns were excluded from the study. These results contrast

with a leading burn surgeon's 50% correct identification rate on the same group of patients on day three post-burn.

- The optical analysis technique is independent of patient age, sex, race, size of burn, burn etiology, or burn location.

- The probability of healing within three weeks of the day of injury, P, for any burn site is given by the following expression:

$$P = e^{x} / (1 + e^{x}),$$

where $x = -7.22 - 5.11\ (G / IR) + 9.22\ (R / IR)$, and R, G, and IR denote the red, green, and near infrared reflectivity of the burn site, measured on the third day post-burn.

APPROACH TO THE PROBLEM

Our approach to the problem of characterizing burn wound healing time, or equivalently, burn depth, on or about the third day post-burn, was to develop a real-time video system that could measure the red, green, and near infrared reflectivity of an entire burn area, and calculate on a point by point basis the probability of burn healing in three weeks. An image of the burn area is displayed on a color video monitor, showing by false color which areas are expected to heal within three weeks, and which areas are not expected to heal within three weeks. This information, along with other clinical signs, can be used to plan the management of the burn wound.

Documentation of the burn is made easy by permitting the operator to freeze either a true-color picture of the burn or the false-color reflectivity analysis on the video terminal, and take an instant 8" x 10" color picture of either image for study or inclusion in the patient's file. Patient information or other data can be placed in a title window which appears on the bottom of the video screen, so that each hard copy picture can be readily identified.

SUMMARY OF WORK ACCOMPLISHED

Phase One: March 15, 1985 - March 14, 1986

During the first phase of our work, the imaging multispectral burn depth indicator (IBDI) was designed and built. Figure 1 shows a block diagram of the instrument. It is operated in the following manner:

A solid-state silicon charge-coupled device (CCD) video camera is focused on the burn wound. The camera sees the subject through a color filter wheel, which rotates in front of the camera lens at 300 rpm. The wheel contains four different filters which transmit narrow-band red, green, blue, and near infrared light. Figure 2 shows the spectral passbands of the filters used. Acquisition of a frame of video information takes 1/30 second. In one mode of operation, video frames are acquired sequentially through the red, green, and blue filters, once each revolution of the filter wheel. These frames are displayed as a true-color image of the selected burn site at a rate of 5 images per second. This mode is used for camera set-up, focusing, etc. At a keyboard command, the true-color image can be frozen on the video display terminal. This permits the operator to take a photograph of the true-color image of the burn under investigation. Another keyboard command places the system in the second mode of operation, and causes three successive video frames to be acquired sequentially through the red, green, and near infrared filters. These frames are digitized and stored in electronic memories. A micro computer then analyzes the information in these three frames, pixel by pixel, and displays, within 30 seconds, a false-color image of the burn wound in which the colors indicate selected ranges of probabilities of burn healing. The meanings of the colors used in the false-color image can be controlled by a simple set-up procedure. Hard copy 8" x 10" photographs or transparencies of the color monitor screen can be obtained simply by loading a film plate into the hard copy unit, exposing the film, and processing the plate in the attached instant film processor. Alternatively, photographs may be taken of the video terminal directly. Patient information can be typed onto the video terminal and displayed on the color images as well.

The entire system is built around a single board microcomputer, which was programmed to accept keyboard commands and control the operation of the video mixer and video display terminal. The design, fabrication, and programming of this system occupied us for the entire first year of the contract. An exceedingly detailed description of the hardware and software developed for the IBDI is contained in the master's thesis presented by DeSoto [7].

The microcomputer, color monitor, hard copy unit, user terminal and storage areas for the camera, tripod, lights and film are all fully enclosed in a mobile cabinet with dimensions of approximately 5' x 4' x 3' (L x H x D). The camera apparatus and high intensity lamp are mounted on a sturdy tripod separate from the main system cabinet and connected to it by a 25 foot cable which allows for flexibility in placing the apparatus in a patient's room.

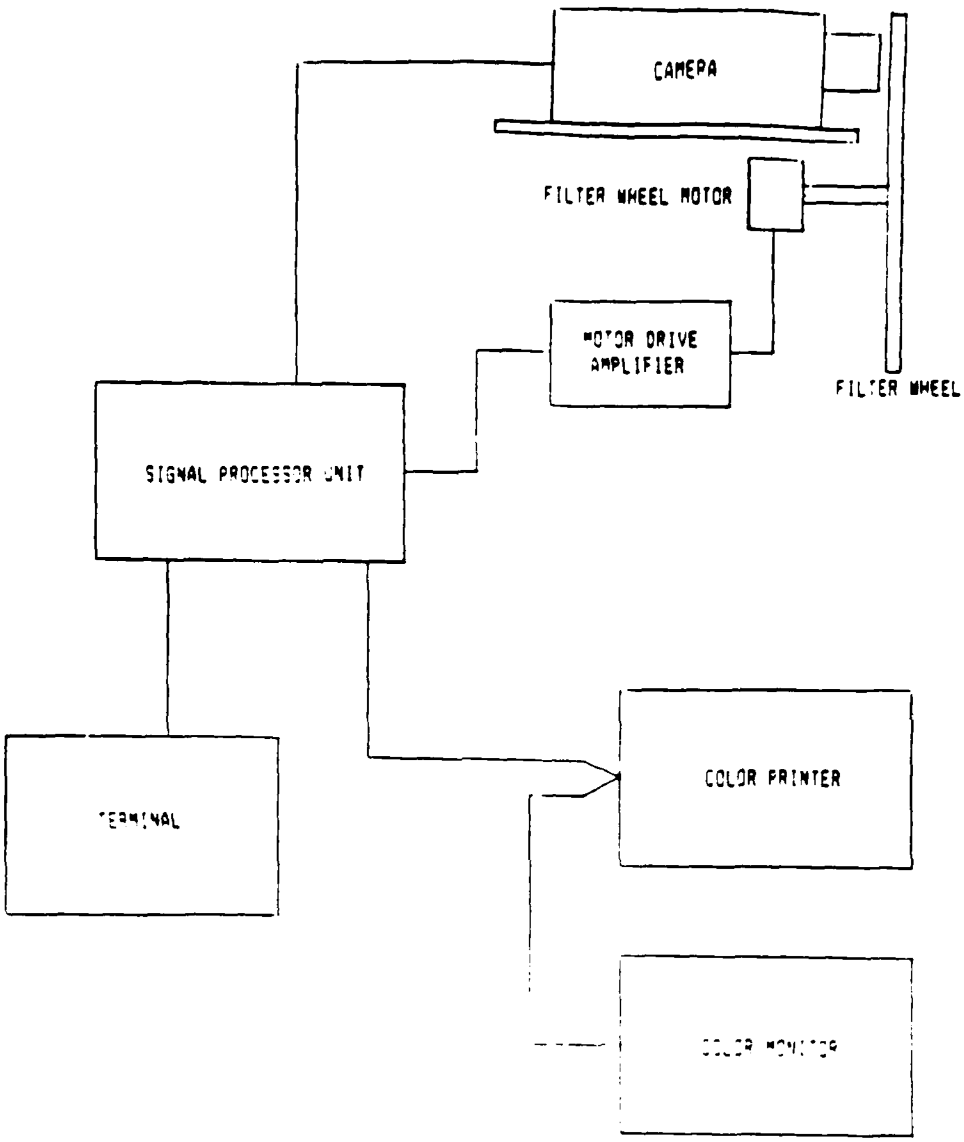


FIGURE 1: BURN DEPTH IMAGING SYSTEM
ONE LINE DIAGRAM

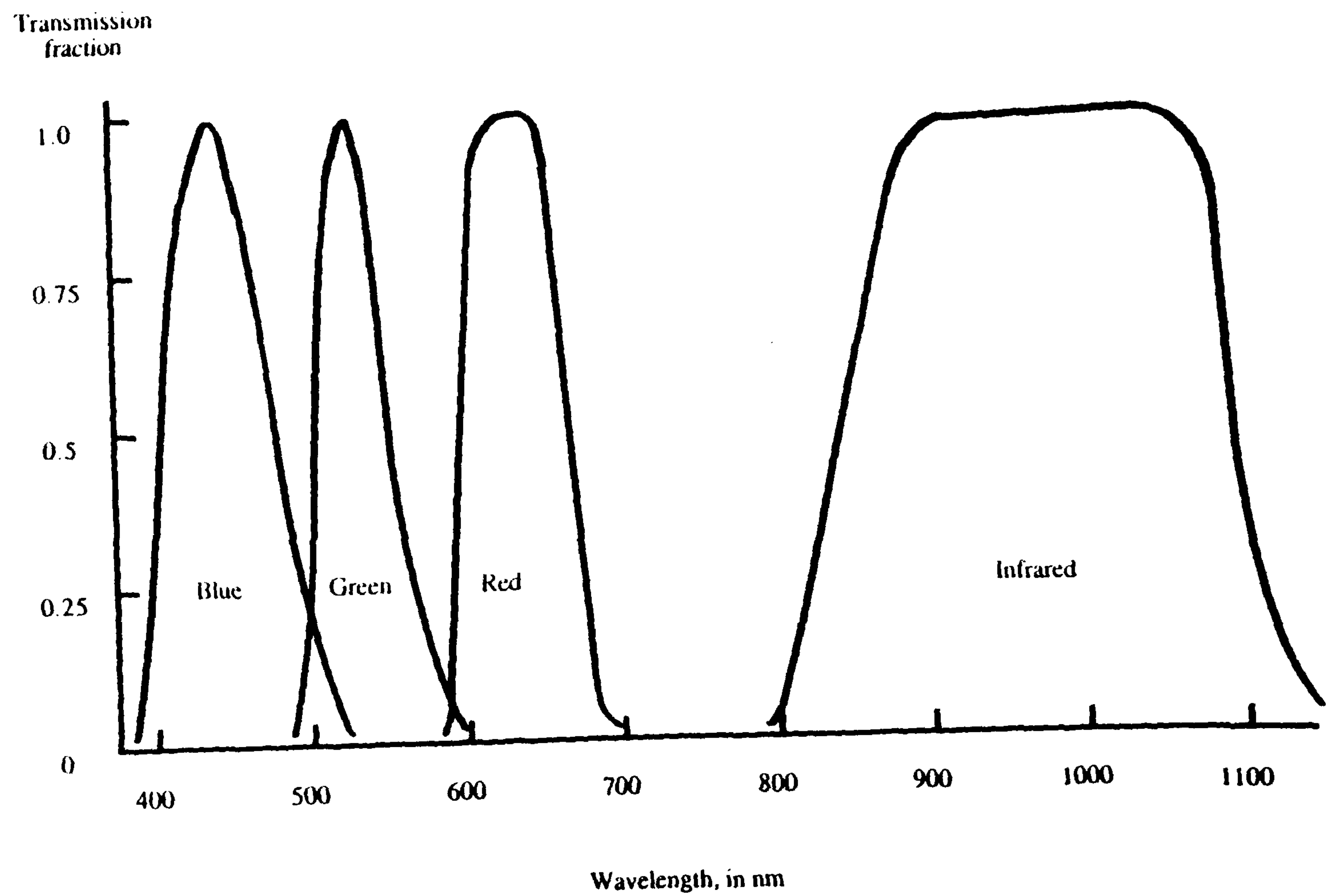


Figure 2: Passbands of filters used in color wheel

Phase Two: March 15, 1986 - March 14, 1987

After the IBDI was built, we embarked upon a year-long clinical study, in cooperation with Dr. David M. Heimbach, Director, Harborview Burn Center, Harborview Medical Center, Seattle. We had two objectives for this study. The first was to compare the accuracy of burn healing prediction of the IBDI with an earlier burn depth instrument developed by us and reported upon [4, 6]. The second objective was to evaluate the operational aspects of the IBDI, including ease of use, reliability, and physician acceptance in the burn center environment.

Approximately 40 patients admitted to the Harborview Burn Center ranging in age from six months to 82 years of age were involved in the clinical study. Any patient with a new burn of greater than approximately 5% total body surface area was eligible to participate. However, data is presented on only 32 of those patients with a total of 112 sites imaged. Due to various factors including the inability to obtain follow up information, lack of surgical information for grafted burns and infection, the other eight patients had to be eliminated from the study. The data collection was accomplished by M. K. Moore, a graduate student under the direction of the principal investigator, assisted by a part-time research nurse who had several years experience as head nurse in the burn center.

The protocol began when a patient was admitted and ended when the wound itself had healed, usually no longer than 30 days. Upon admission, the research nurse visited with the patient and made an initial assessment to determine if the patient qualified for the study. If qualified, the clinical study was discussed with the patient. A written experimental protocol, a brief description of the IBDI, an explanation of the procedure and a copy of the consent form was given to the patient to consider overnight. On the second day, the patient was visited again and if consent was obtained (for children, parental consent was obtained) the burn site was sketched on body part diagrams to permit relocation for follow up. The number of burn sites to be evaluated on each burn wound was chosen at the time of imaging and numbered on the gridded body part sheet. The sites were chosen in order to best represent the complexity and extent of the burn.

All images were taken on the third day post-burn since previous studies [4, 6, 9, 10] had demonstrated that during the first 48 hours after injury, burn wounds are unstable. The images were taken after either the morning or afternoon hydrotherapy and debridement (commonly referred to as tanking) so that the wounds would be free of organic slough, medication or antibacterial creams. The imaging process is painless with the only discomfort resulting from the wound being open to air during the procedure. For each burn site we obtained a true-color image, a false-color image, and a measurement of the red/infrared and green/infrared reflectivity, provided by an instrument designed and built for an earlier clinical study [4, 6]. The false-color images generated by the IBDI were composed of four colors, which represent the following:

Blue	=	an area with a	75% - 100%	probability of healing within 21 days
Green	=	"	50% - 75%	"
Yellow	=	"	25% - 50%	"
Red	=	"	0% - 25%	"

It is important to note that the false-color representation of normal skin is variable and of no consequence since it depends upon the pigmentation of the individual. Both the true-color and corresponding false-color images were included in the patient's clinical study file. At the time of imaging, one of three attending burn surgeons was asked to make a clinical assessment of each burn site, stating either that the burn site will heal within 21 days or will not heal within 21 days. The physicians were not given any information about the IBDI's healing prediction, to avoid biasing their judgments. The sites were monitored for final outcome by follow up with the patient at clinic appointments which were scheduled regularly after discharge. For those sites which were not grafted, the number of days to healing was recorded. For those burn sites which were grafted, the surgeon was asked to confirm or modify his earlier clinical assessment at the time of excision and grafting. The research nurse was present during these surgical procedures to assure that the surgeon knew precisely which sites we were interested in, and to record the surgeon's comments.

In addition to the data described above, additional patient information was obtained in order to determine if any other factors were significant in assessing burn depth. These are:

1) Age and sex of patient
2) The body site according to six categories
3) The etiology of the burn (burn type according to four categories)
4) The total body surface area of the burn (TBSA)
5) A medical history and any possible complications

Race was not included since the pigmented epidermis is generally sloughed during debridement and does not contribute to the optics of a wound.

RESULTS

We include several sets of images, both true-color and false-color, to demonstrate the quality of the output of the IBDI. Figures 3 - 5 illustrate three burns of different etiology and depth. For each burn wound the upper photograph presents a true-color image of the burn and the lower photograph shows the corresponding false-color image. As discussed previously, all images were taken on the third day post-burn.

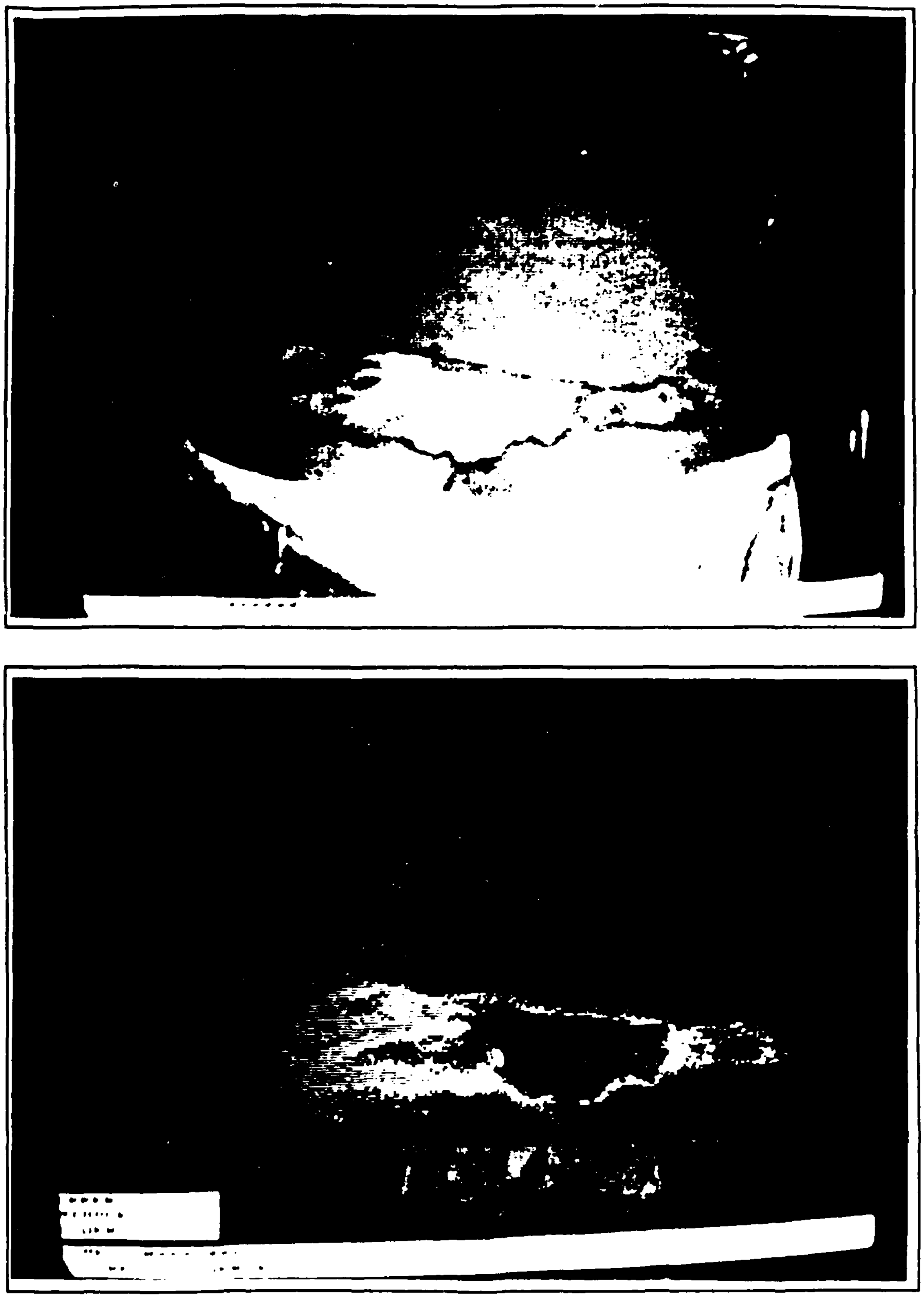
In the first pair of photographs (figures 3a and b), a contact burn on the palm of an 82 year-old woman is shown. The burn is clearly superficial. A visual indication of this classification is the red, vascularized appearance of the wound. The false-color image is purely blue (greater than 75% probability of healing within 21 days) showing the uniformity of the site. This burn site completely re-epithelialized within six days.

The second pair of photographs (figures 4a and b) show a scald burn on the foot of a 65 year-old black, diabetic female. The burn sites vary in depth as demonstrated by the different false-colors. The area on the lateral side of the foot was a burn of superficial thickness with the majority of the site imaging in blue. The healing time for this site was twelve days. This healing time may appear to be high, but it is probably due in part to the diabetic condition of the patient which can affect the healing response, in particular, the blood supply to the extremities. The wounds on the top of the foot were of varying depths. The area of the burn on the top center which imaged red did not heal within three weeks, but inspection of the corresponding region of the true-color image shows a slight glare reflection from the light source. This high intensity specular reflection can have an effect on the false-color image. Specular reflection regions tend to image red independent of the actual burn depth. This specular interference occurred only infrequently. In the cases where specular reflections did appear, the wounds generally had been left open to air for a longer period of time and fluids had begun oozing from the site. We have since found that the use of crossed polarizers on the light source and camera lens provides a very effective solution to this problem.

The final pair of photographs (figures 5a and b) were taken of a 21 year-old white male who suffered a tar burn to his lower back. By comparing the several different regions of the burn wound, one can see the discriminative capabilities of the IBDI. Pixel by pixel resolution renders a detailed contour map of the burn wound. In this case, the entire burn wound was grafted even though some areas were clearly less deep. This is often done since it can be difficult to create a mosaic graft and it is often much more effective to cover the entire area. In this example, the IBDI's predictive accuracy and spatial resolution were beyond what was clinically necessary. However, this burn was relatively small in area and large surface area burns are of much graver concern. When a large percentage of the body is burned, there is less unburned skin for grafting. Because it is always desirable to use autographs, the IBDI's pixel by pixel resolution would be of great value in determining which sites absolutely required grafting and identifying areas of the burn which could be left to heal on their own.

Figures 3a and b: 3a shows the true color image of a contact burn on an 82 year-old white female. 3b shows the corresponding false color image The burn healed in six days

Figures 4a and b: 4a shows a true color image of a scald burn on a 65 year-old diabetic, black female 4b shows the corresponding false color image. The lateral site healed in twelve days



Figures 5a and b: 5a shows the true color image of a tar burn on a 21 year-old white male. 5b shows the corresponding false color image. Although some areas were clearly less deep than others, the entire site was grafted.

Aside from the clinical value of the IBDI in providing hard-copy documentation of the burn wound, the instrument's value as a predictor of burn healing is best demonstrated by comparing its accuracy of burn outcome prediction with that of the burn surgeons. Table 1 shows this data for all 112 sites studied. The burn sites are divided into two classes, those that were predicted to heal within a 21 day period and those that were not. In each case there is a significant difference between the prediction accuracy of the burn physicans and the IBDI.

Table 1
Physician vs. IBDI

All 112 sites

	Predicted to Heal in < 21 Days		Predicted to Heal in > 21 Days	
	By Physician	By IBDI	By Physician	By IBDI
Correct # (%)	51 (76%)	59 (91%)	30 (67%)	40 (85%)
Incorrect # (%)	16 (24%)	6 (9%)	15 (33%)	7 (15%)

Inspection of Table 1 shows that the IBDI was correct 91% of the time for burn sites predicted to heal within 21 days, and was correct 85% of the time for burn sites which were not predicted to heal within 21 days. The predictions of the burn surgeons were marginally less accurate.

It has been demonstrated that a physician has little difficulty in predicting the healing outcome of burns that are either clearly superficial or clearly full thickness. For those burn wounds which are not either clearly superficial or clearly full thickness, the situation is different. In these cases, we have found [4 - 6] that experienced burn surgeons are sometimes unwilling to make burn healing predictions as early as day three post-burn because of the uncertainty surrounding the estimate. We were interested to test the accuracy of the predictions of the IBDI and the surgeons on a group of burn sites whose prognoses was more difficult. Thus, we selected those burn sites that were judged by the IBDI to have burn healing probabilities between 25% and 75%. There were 55 such sites. The following table shows the accuracy of burn healing predictions made by the IBDI and by the physicians on these burns.

Table 2
Physician vs. IBDI

for 55 sites of intermediate depth

	Predicted to Heal in < 21 Days		Predicted to Heal in > 21 Days	
	By Physician	By IBDI	By Physician	By IBDI
Correct # (%)	24 (71%)	31 (86%)	10 (48%)	15 (79%)
Incorrect # (%)	10 (29%)	5 (14%)	11 (52%)	4 (21%)

As expected, the accuracy of prediction of both the physicians and the IBDI was reduced for this group, due to the increased difficulty in assessing these burns. For burns predicted to not heal within 21 days, the physicians were accurate only 48% of the time compared to 79% for the IBDI. This difference is statistically significant.

Of the 112 burn sites studied, 67 were not grafted. For these sites, therefore, we know how many days were required for the burn wound to heal (denoted by regrowth of the epithelium). Analysis of these data reveal that the four false-color predictive regions of the IBDI classified these sites into four distinct groups whose average number of days to healing differed from one another by approximately one week. Table 3 illustrates this result.

Table 3
Average Days to Healing
for 67 Non-Grafted Burn Sites

Healing Probability Range	Mean Days to Healing	St. Dev.	95% Confidence Interval
0% - 25%	30.7	3.2	± 2.0
25% - 50%	24.5	6.9	± 4.1
50% - 75%	14.4	3.9	± 1.6
75% - 100%	10.3	3.1	± 2.1

Each burn site healed within two standard deviations of the mean for its group. Our confidence in the mean days to healing for each group is 95% within the confidence interval indicated.

The following table shows the complete correlation matrix for all variables. The matrix lists the r values for each pair of variables 1 - 7. It should be noted that the variables denoted by Physican's Prediction and IBDI's Prediction mean simply whether or not the site was predicted to heal within 21 days. There is no correlation with final outcome indicated in this table.

Table 4
Correlation Matrix

Variable:	1	2	3	4	5	6	7
1. Burn Type	-						
2. Sex	0.00	-					
3. Age	0.40	0.02	-				
4. TBSA	0.25	0.01	0.32	-			
5. Physician	0.00	0.00	0.00	0.00	-		
6. Physician's Prediction	0.50	0.10	0.25	0.00	0.00	-	
7. IBDI's Prediction	0.10	0.10	0.05	0.00	0.07	0.70	-
8. R, G, and IR Data	0.11	0.15	0.02	0.00	0.00	0.65	0.95

The above correlation matrix confirms previous work [4, 6] that indicated that age, sex, and total body surface area of burn (TBSA) do not correlate with the healing prediction. There is a small correlation ($r = .40$) of patient age to burn type. Perhaps this is indicative of the fact that the scald burns were more prevalent among the children in the study. There is also a small correlation ($r = .50$) of the physician's prediction with burn type. More on this later. The strongest correlation was between the IBDI's predictions and the measurements of red, green and near IR reflectivities. This result was expected, of course, since the prediction algorithm built into the IBDI is based upon spectral analysis of the burn site in the red, green, and near infrared wavelength bands. The correlation simply indicates that the IBDI is making the proper spectral measurements and processing the data correctly.

DISCUSSION OF RESULTS AND CONCLUSIONS

The quantitative analysis of results presented in the preceding section depends to some degree on qualitative assessments. For example, the number of days to healing is really only accurate to within one day either side. This judgment is further suspect because it was often made by the untrained out-patients and reported to the project nurse. In the case of grafted burns, where days-to-healing has no meaning, the burn surgeon was twice asked to make a healing prediction for each site, once on post-burn day three, and once again during excision. It was this latter assessment, as to whether the surgeon still thought the burn site would or would not heal within 21 days <u>if not excised</u> that was recorded as the outcome for that site. While in surgery, the physician is able to make conclusive determinations of burn depth since he is able to tangentially excise the burn until a viable bed of tissue is reached. Absolute burn depth, of course, must be regarded in the context of the normal total skin thickness at that body site in order to predict burn healing potential. Thus, the burn healing prediction, even in surgery, is a subjective call based upon the experience of the surgeon. However, it was very interesting to observe the surgeons' predictions at the time of excision. For the most part, the surgeons did not change their prediction at the time of excision. In effect, if the burn surgeon predicted on the third day post-burn that the burn would not heal within 21 days, he did not change his prediction at the time of surgery. As a result, the accuracy of the instrument's predictions may have suffered (and the surgeon's accuracy may have increased) as a result of the natural reluctance of the surgeon to change a prediction which may have been incorrect in the first place. After all, the patient was in surgery, with the burn ready to be excised. Furthermore, if a burn is a mosaic burn having partial and full thickness areas, the general practice is to graft the entire site. Therefore, sites which would have healed on their own were sometimes grafted and

categorized as a non-healing site. This is often true of sites on the periphery of a burn. This introduced a source of error and bias in the data as well.

Since three different burn surgeons made site predictions for this study, we were able to observe differences in prediction accuracy. The percentages of accurate predictions made by the three surgeons (as assessed by the number of correct predictions divided by the total number of predictions made) ranged from 53% - 89%. Thus, there is a large variation in burn healing prediction accuracy even for experienced burn surgeons.

Table 4 offers some insight into a possible source of error on the part of the physicians. As noted above, the physicians' predictions were correlated (r = 0.50) with the type of burn. On the other hand, the prediction of the IBDI was essentially uncorrelated (r = 0.10) with this variable. Since the accuracy of prediction of the IBDI exceeded that of the surgeons, we are forced to conclude that the surgeons may be predisposed to view certain types of burns as being deeper, and other types of burns as shallower, than they really are. The data suggests that the IBDI, which is not subject to this prognostication bias, could be used to the advantage of the patient in reducing the incidence of unnecessary surgery in the first case, and permitting earlier tangential excision and reduced hospitalization time in the second case.

Our clinical experience with the Imaging Burn Depth Indicator at Harborview Burn Center has been extremely positive. All the surgeons and staff who observed the operation of the instrument were eager to see it remain in the hospital, and wanted to have it integrated into the normal patient assessment procedure. We believe, however, that the prototype IBDI can be improved in several areas, and that this should be done before it is released for unsupervised clinical use.

RECOMMENDATIONS

We recommend most emphatically that the technology developed under this contract be made available to the public in an expeditious manner. To this end, the University of Washington is presently conducting technology transfer discussions with a number of companies.

The instrument itself works very well when set up properly. We recommend, however, a number of specific changes that would make the IBDI easier to use:

1) The instrument as described in reference [7] is subject to error in the false-color imaging mode when the intensity of light reflected from the subject in any wavelength band causes the video digitizer or frame buffer to overload. By careful placement of the illumination and proper selection of the camera iris, this problem can be controlled. We recommend that an improved instrument provide a warning message to the instrument operator when overload occurs.

2) As mentioned previously, specular reflection can cause erronious false-color images to be produced. This problem is related to higher-than-normal reflected light levels mentioned above. Specular reflection can be effectively eliminated by illuminating the subject with linearly polarized light, accomplished by placing a polarizing filter in front of the lamp, and placing a crossed polarizing filter in front of the camera lens.

3) We have found that the 8" x 10" instant video printer built into the current prototype for making hard-copy photographs from images displayed on the color video monitor is not instant enough for clinical use. The equipment requires several minutes to record an image, and several more minutes to process the negative. During the recording phase, the IBDI cannot be used for anything else. This delay can cause excessive patient discomfort since the burn wounds must be left exposed during imaging, and takes the operator's attention away from the patient. The problem was solved in our clinical work by photographing the video screen with a 35 mm camera, set up on a tripod. The film must then be processed before hard-copy images are available to the physician. We recommend that an improved IBDI incorporate a video cassette recorder to acquire all images

electronically during the patient session. These images can then be played back after the session, and recorded using the instant video printer at a more convenient time.

4) The false-color images of a burn clearly denote regions of different burn depth. Furthermore, the color boundaries can be selected by the operator. We believe it would be possible to extend the functions of the IBDI to permit it to calculate the percentage of body surface area affected by burns of different depths. This evaluation is presently made on all patients by purely subjective graphical methods (depending on the body shape, each body part has an approximate suface area percentage). The three dimensional nature of the subject must be taken into account properly, of course. The analysis of two dimensional video images of three dimensional objects is under current investigation by researchers developing methods for machine vision. At the present time, we do not recommend that a development program be mounted to add this function to the IBDI, but we do suggest that the feasibility and cost effectiveness of this enhancement be reviewed from time to time, as improved techniques are developed by machine vision researchers.

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